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POLYURETHANE FOAMS FOR AIRCRAFT SHOCK MOUNTS. IV. OTHER POLYOLS--ETC(U)
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A number of polyether polyurethane flexible foams are being developed as shock mitigators for electronic equipment aboard Navy aircraft. These foams are based on polyol mixtures derived from poly(oxytetramethylene)glycol and poly(oxypropylene)polyol. This report describes the effect that changes in the basic polyol composition has on the foam's vibration damping and mechanical properties.

FOREWORD

Foams are used aboard Navy aircraft to protect electronic equipment from shock and vibration damage. This program was designed to develop new foam formulations which were hydrolytically stable and had vibration damping and mechanical properties which met the specifications outlined in MIL-F-81334B(AS). This report describes the effect that changes in the polyol composition of a previously developed foam system had on the properties of interest.

This program was funded by the Naval Air Systems Command (AIR-5163D2) under AIRTASK A510-510C/001-4/9510-000-002 as part of a materials deterioration block program administered by the Naval Air Development Center.

Dr. H. Booth is recognized for his contributions during the early stages of the program and Dr. H. Miller of the General Plastics Manufacturing Company is acknowledged for the fabrication of the foams described in this report.

J. GOFF
By direction

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INTRODUCTION

Polyester polyurethane foams have been used as vibration damping materials for many different applications in the past. These foams have good mechanical properties and excellent resistance to a variety of fuels and other organic fluids, but they are subject to hydrolytic degradation. Conversely, polyether polyurethane foams while not generally as strong or resistant to fuels as the polyesters do have good hydrolytic stability and can also be formulated to have the required vibration damping properties. Polyether polyurethane foams are used therefore when prolonged exposure to high humidity environments would cause deterioration and mechanical properties losses in the polyester polyurethane foams.

The Navy is presently using vibration damping foams aboard aircraft to protect sensitive electronic equipment from the shock and vibration experienced during take-offs and landings from the deck of an aircraft carrier. When the originally used foam was withdrawn by the manufacturer, a program was initiated by NAVAIR to find a suitable commercial substitute or to develop a new foam system. NSWC/WO was tasked to carry out this program using MIL-F-81334B(AS) as guidance. A series of foams based on a mixture of poly(oxytetramethylene)glycol and poly(oxypropylene)glycol with toluene diisocyanate gave the best overall results.[1,2] The properties which were measured and used in making this determination were compressibility, rebound, tensile strength, elongation, hydraulic fluid and hydrolytic resistance, porosity and vibration damping. The best foams from this series were then fabricated into slabs using techniques which gave foams having the same cell sizes and cell counts that would be anticipated had these foams been manufactured on production type foam equipment. Several of these NSWC foams met all of the vibration damping criteria of the MIL-F-81334B(AS) but only certain formulations could meet the strength requirements.[3] Modified formulations were then studied in an attempt to upgrade the mechanical properties of the existing foam systems without adversely effecting their excellent vibration damping characteristics. The results of this investigation are the subject of this report.

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[1] Booth, H. J. and Duffy, J. V., "Polyurethane Foams For Aircraft Shock Mounts, I, Polyether Based Foams," NSWC/WOL TR 78-125, July 1978.

[2] Booth, H. J. and Duffy, J. V., "Polyurethane Foams for Aircraft Shock Mounts, II, Polybutadiene Based Foams," NSWC/WOL TR 78-162, Nov 1978.

[3] Duffy, J. V., "Polyurethane Foams for Aircraft Shock Mounts, III, Vibration Damping by Polyether Foams," NSWC TR 80-343, July 1981.

EXPERIMENTAL

A. FOAM FABRICATION.

The formulations discussed in this report were made by the General Plastics Manufacturing Company in Tacoma, Washington. Three different polyol systems were used in this study and four different polyol ratios were made from each system for a total of twelve different foams. The basic system previously reported[3] was based on polyol mixtures of Pluracol 718 and Polymeg 2000. The modified foams were based on the following polyol combinations: Pluracol 718/Teracol 650, Pluracol 381/Polymeg 2000 and Pluracol 684/Polymeg 2000. The polyol ratios used in each case were 80:20, 60:40, 40:60 and 20:80 and all of these foams were formulated to have a density of approximately 4 lb/cu.ft. The formulations for each of the twelve foams are listed in the appendix of this report and are identified by a code which describes in order: polyol ratio, foam density, type of surfactant and the new polyol. For example, 802004BPL381 refers to a modified foam in which Pluracol 381 (PL 381) has been substituted for Pluracol 718 in the basic polyol system. The first four numbers describes the ratio of polyols in this new foam as 80 parts of Pluracol 381 to 20 parts of Polymeg 2000 at a density of 4 lbs/cu.ft. The polyol ratio always designates the Pluracol polyol first followed by that for Polymeg 2000 or Teracol 650. The letter B in the code refers to the use of B3136 as the surfactant, while the letter D in other codes refers to DC 196.

The foam components were added in the order given in the appendix and premixed before the addition of the toluene diisocyanate. An isocyanate index of 105 was used for all of these foams and postcuring was done at 110°C for 30-35 minutes. All weighings were made on a Mettler PC-4400 balance and the weights are reported in grams.

B. VIBRATION DAMPING.

Foam samples (5x5x1") were bonded to aluminum plates (Figure 1) using an epoxy adhesive. The foam sample was then mounted on a Ling electrodynamic vibrator (Figure 2) which controlled and maintained the input vibration over the levels and frequency ranges specified by MIL-F-81344B(AS). Further details of the equipment and its operation can be obtained from the previous report[3] on this work.

C. DENSITY MEASUREMENT.

Density measurements were made according to ASTM D1564-71 on the vibration damping specimens.

D. TENSILE STRENGTH/ELONGATION.

Tensile strength and elongation measurements were made in accordance with ASTM D1564-71.

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[3]See footnote 3 on page 5.

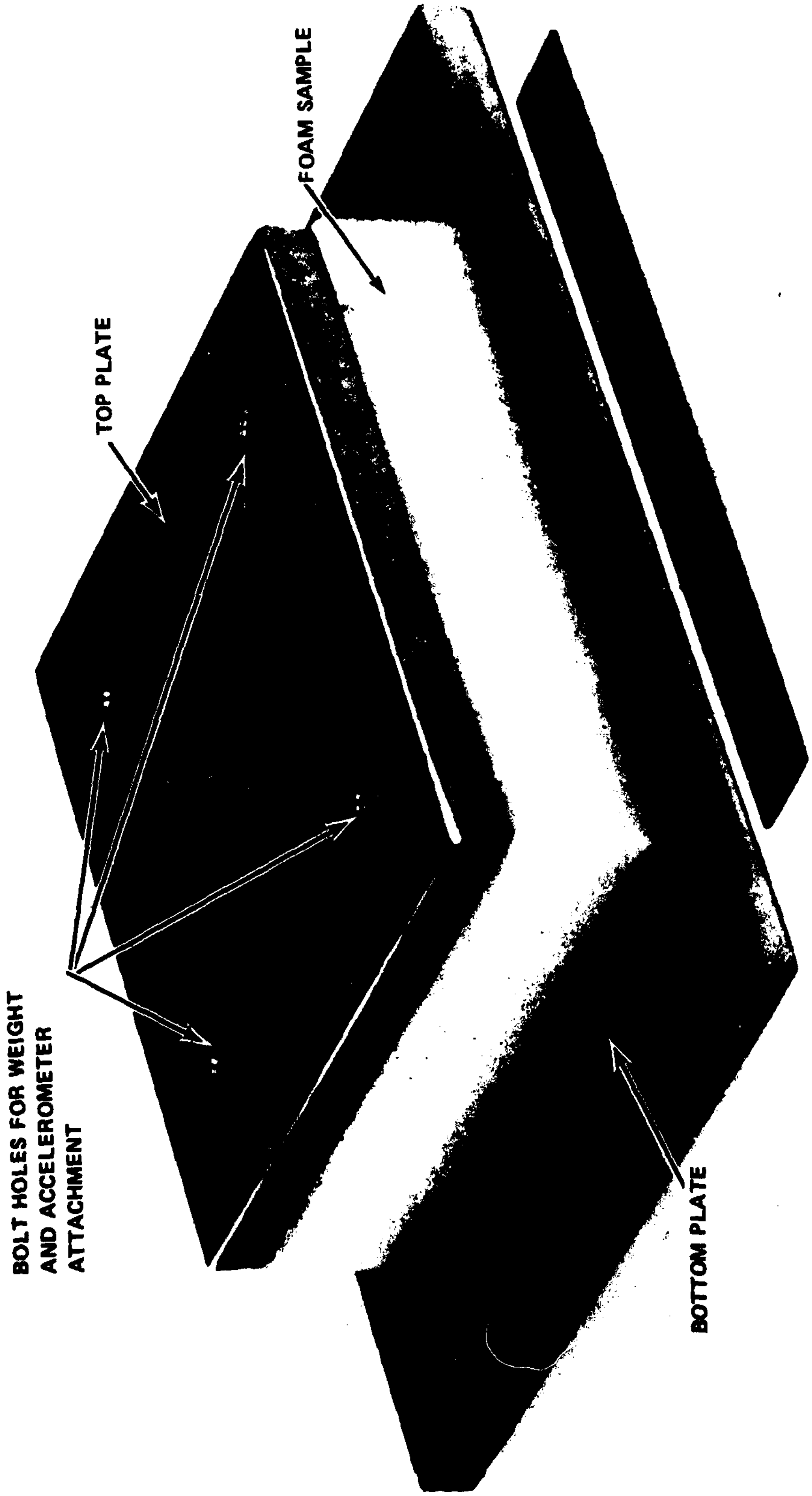

FIGURE 1 FOAM VIBRATION SAMPLE

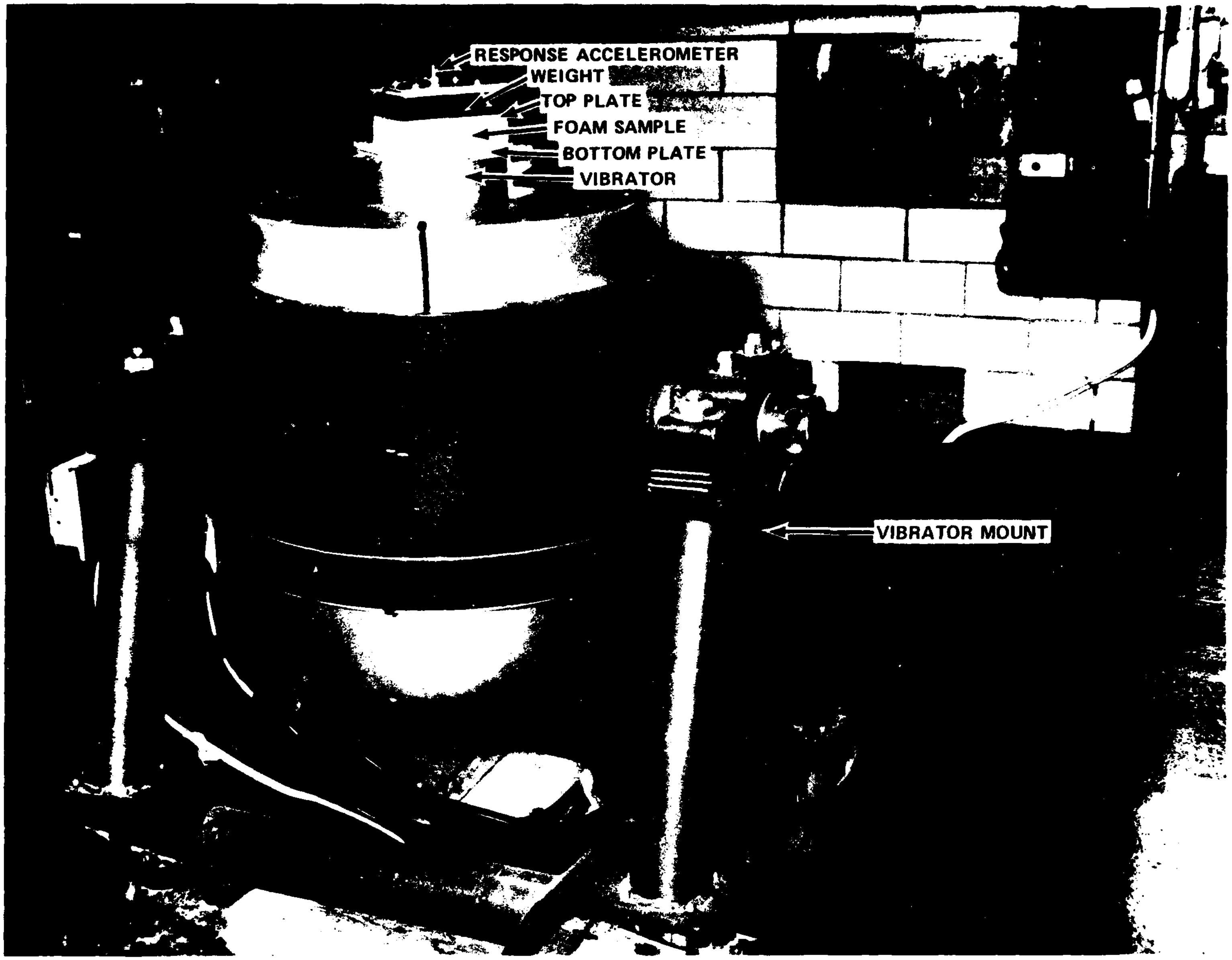

FIGURE 2 LING ELECTRODYNAMIC VIBRATOR

DISCUSSION OF RESULTS

A. VIBRATION DAMPING.

The MIL-F-81334B(AS) specification for input vibration is shown in Figure 3 in which input acceleration (g) is plotted against frequency (Hz). The output acceleration and transmissibility envelopes which are plotted on the same graph define the limits of acceptable response from the foam under the conditions of the test.

The vibration output and transmissibility curves for NSWC foams based on a Pluracol 718/Teracol 650 polyol mixture are shown in Figures 4 and 5. In this modified system, the molecular weight of the poly(oxytetramethylene)glycol has been reduced from MW 2000 (Polymeg 2000) to MW650 (Teracol 650). This substitution of Teracol 650 for Polymeg 2000 has produced an improvement in the vibration damping properties so that all four polyol ratios (208004BT650 to 802004BT650) have outputs and transmissibilities which fall within the guidelines established by MIL-F-81344B(AS). Some reduction in damping occurs as the Pluracol 718 content increases.

The damping results for the foam system derived from Pluracol 381/Polymeg 2000 are shown in Figures 6 and 7. This foam system did not damp vibration as well as the Teracol 650 based foams. The following resonance peaks were recorded which exceeded the output acceptability envelope: 208004DPL381 - 43.89 Hz, 40604BPL381 - 28.77 and 60.00 Hz, 604004BPL381 - 41.38 and 47.00 Hz. In addition, the output from all of the PL 381 foams exceeded the envelope in the inflection region at 100 Hz. The transmissibility curves which record the output/input are another method of representing the damping results and clearly indicate identical excursions outside the transmissibility envelope at the same frequencies as previously discussed for the output data.

The third modified system which was evaluated consisted of polyol mixtures from Pluracol 684 and Polymeg 2000. The vibration output curves for foams 208004BPL684 to 802004DPL684 are shown in Figure 8 while the transmissibility data appear in Figure 9. This series of foams gave mixed results. The 406004DPL684 and 604004DPL684 foams had vibration damping which met the requirements of MIL-F-81344B(AS). The 208004BPL684 foam had resonant vibration at 44.33 Hz which exceeded the envelope and showed another excursion outside of the acceptable limits in the 100 Hz region. Finally, 802004DPL684 had a high transmissibility between 37.50 and 500 Hz and could not be used for this particular damping application.

B. MECHANICAL PROPERTIES

A series of polyether foams based on polyol mixtures of Pluracol 718 and Polymeg 2000 were developed by NSWC as vibration damping materials. The best vibration damping properties were shown by the foams that had the high Pluracol 718 contents. These same compositions had tensile/elongation properties which did not meet the MIL-F-81334B specifications. Modifications of the basic PL 718/PM 2000 polyol composition were studied in an attempt to improve the mechanical properties of the foam system (Table 1).

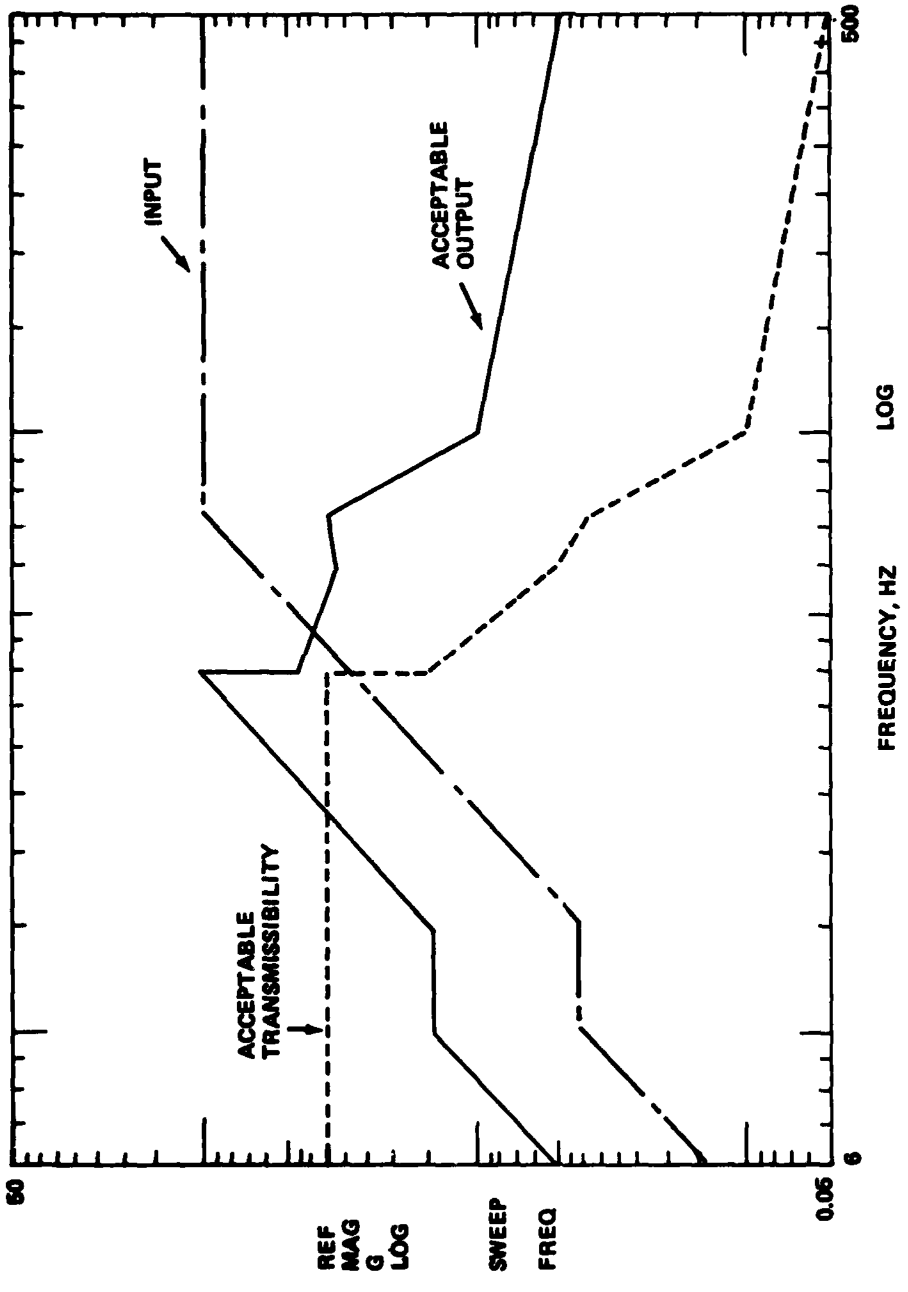

FIGURE 3 MIL-F-81334B (AS) – VIBRATION DAMPING SPECIFICATION FOR POLYURETHANE FOAM

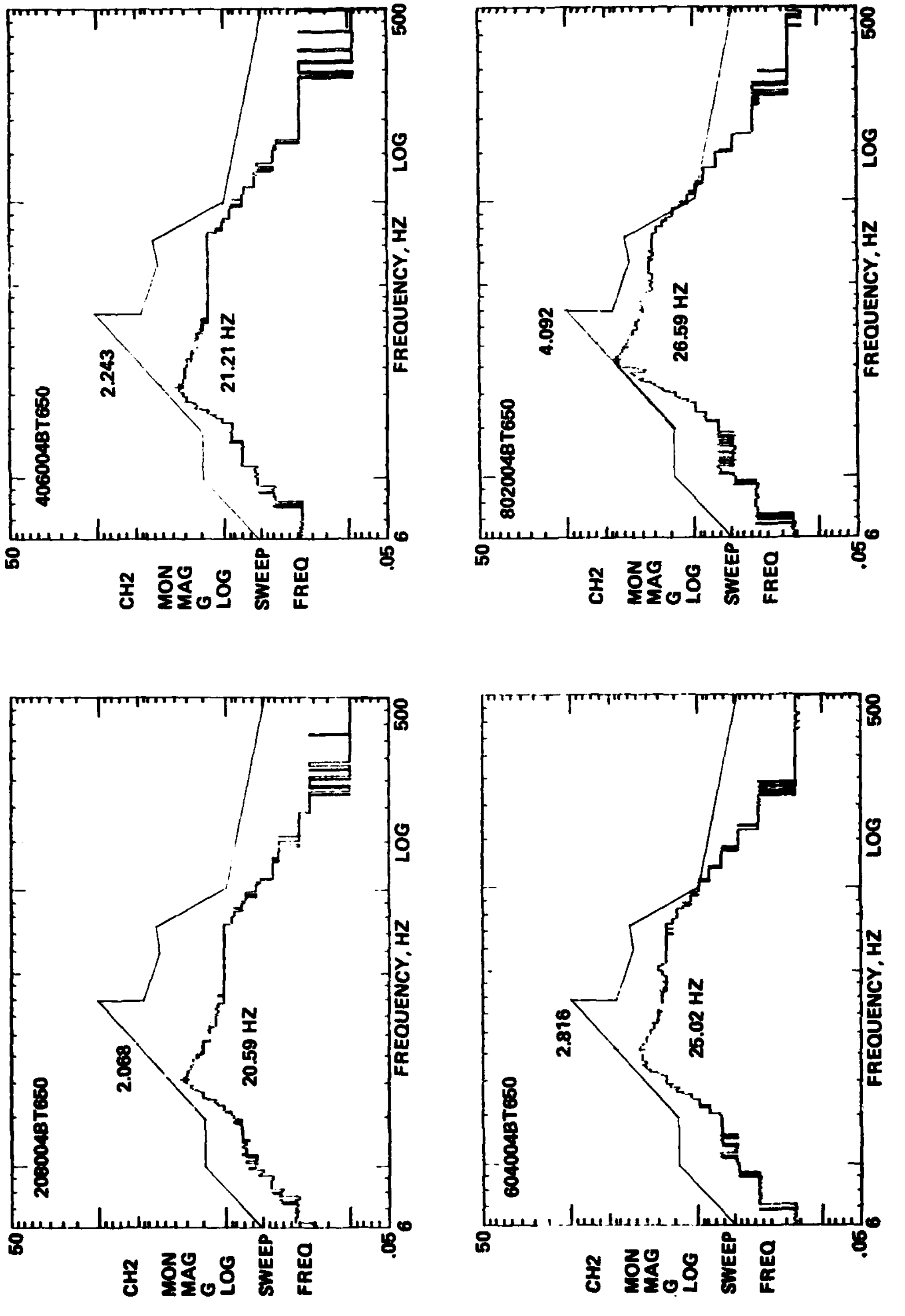

FIGURE 4 VIBRATION OUTPUT FOR NSWC FOAMS 208004BT650 TO 802004BT650.

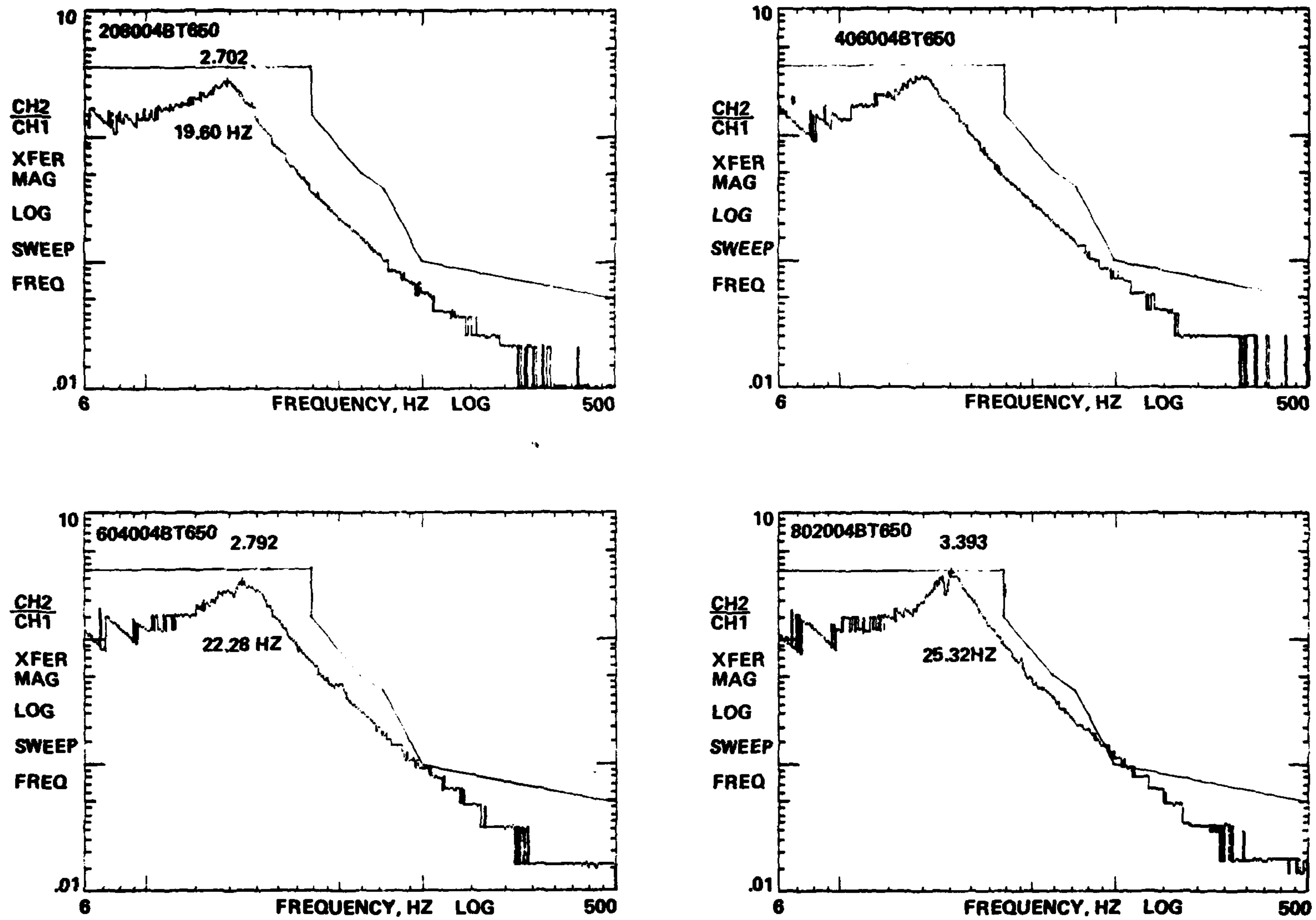

FIGURE 5 VIBRATION TRANSMISSIBILITY FOR NSWC FOAMS 208004BT650 TO 802004BT650.

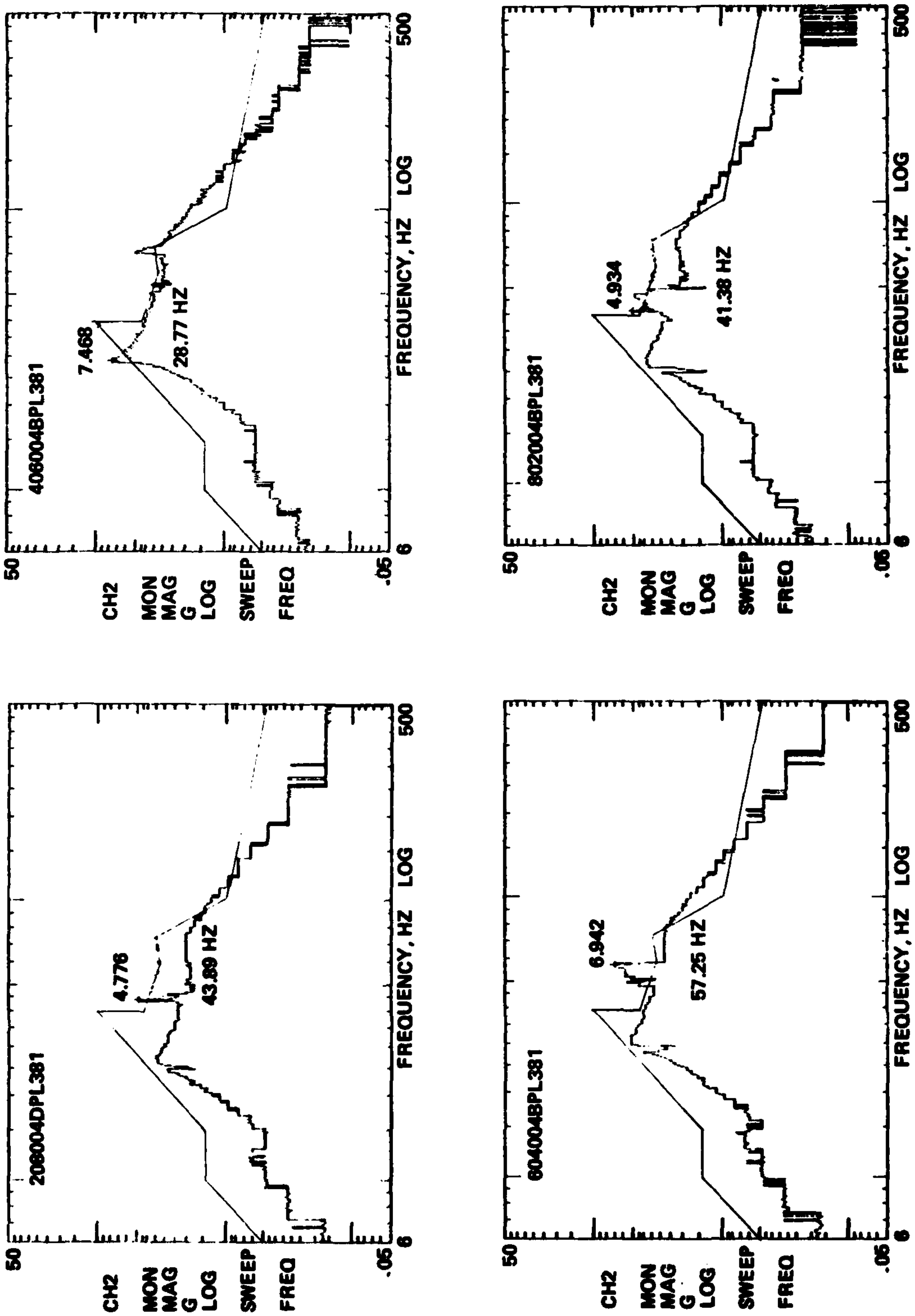

FIGURE 6 VIBRATION OUTPUT FOR NSWC FOAMS 206004DPL381 TO 802004BPL381.

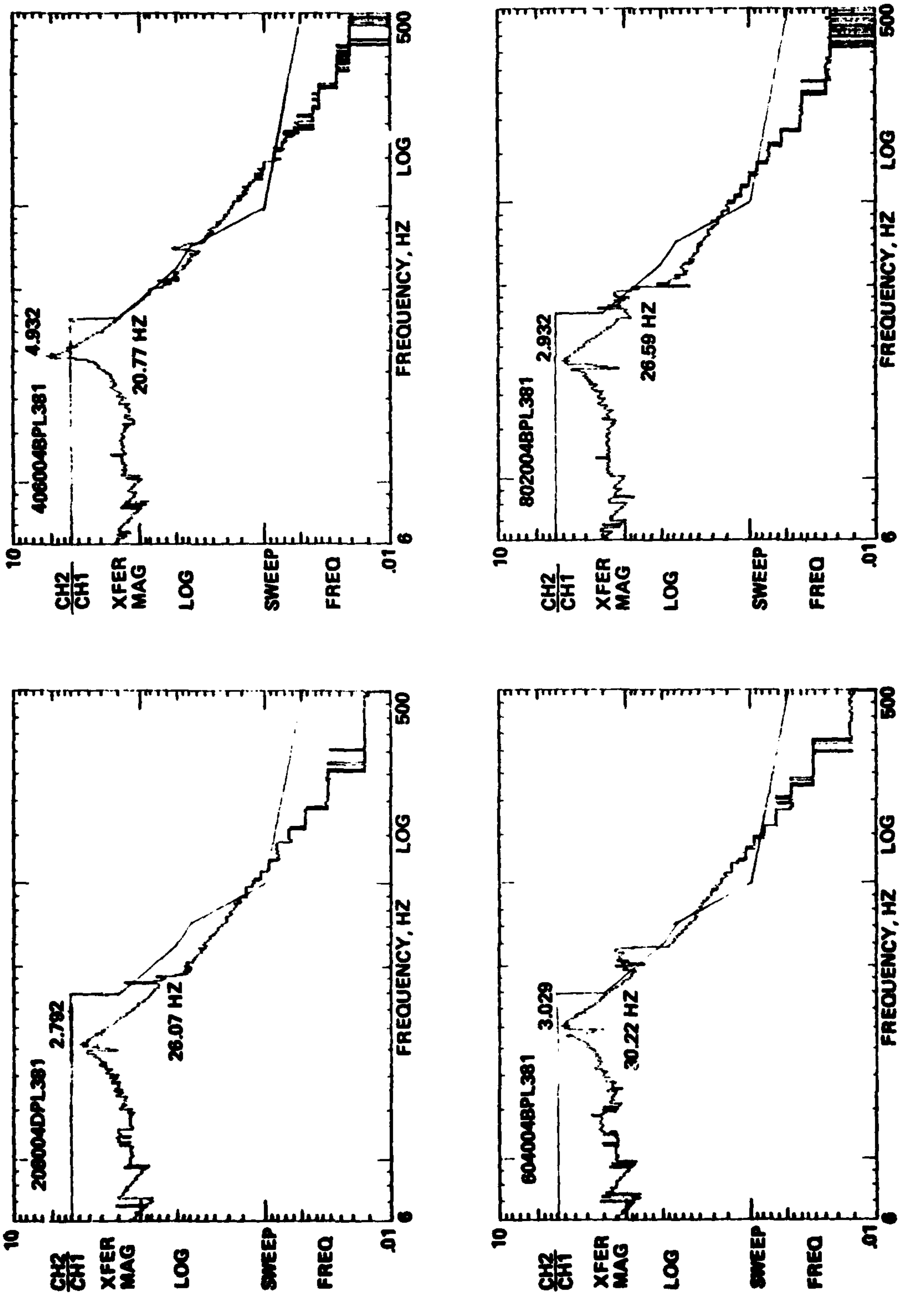

FIGURE 7 VIBRATION TRANSMISSIBILITY FOR NSWC FOAMS 208004DPL381 TO 802004BPL381.

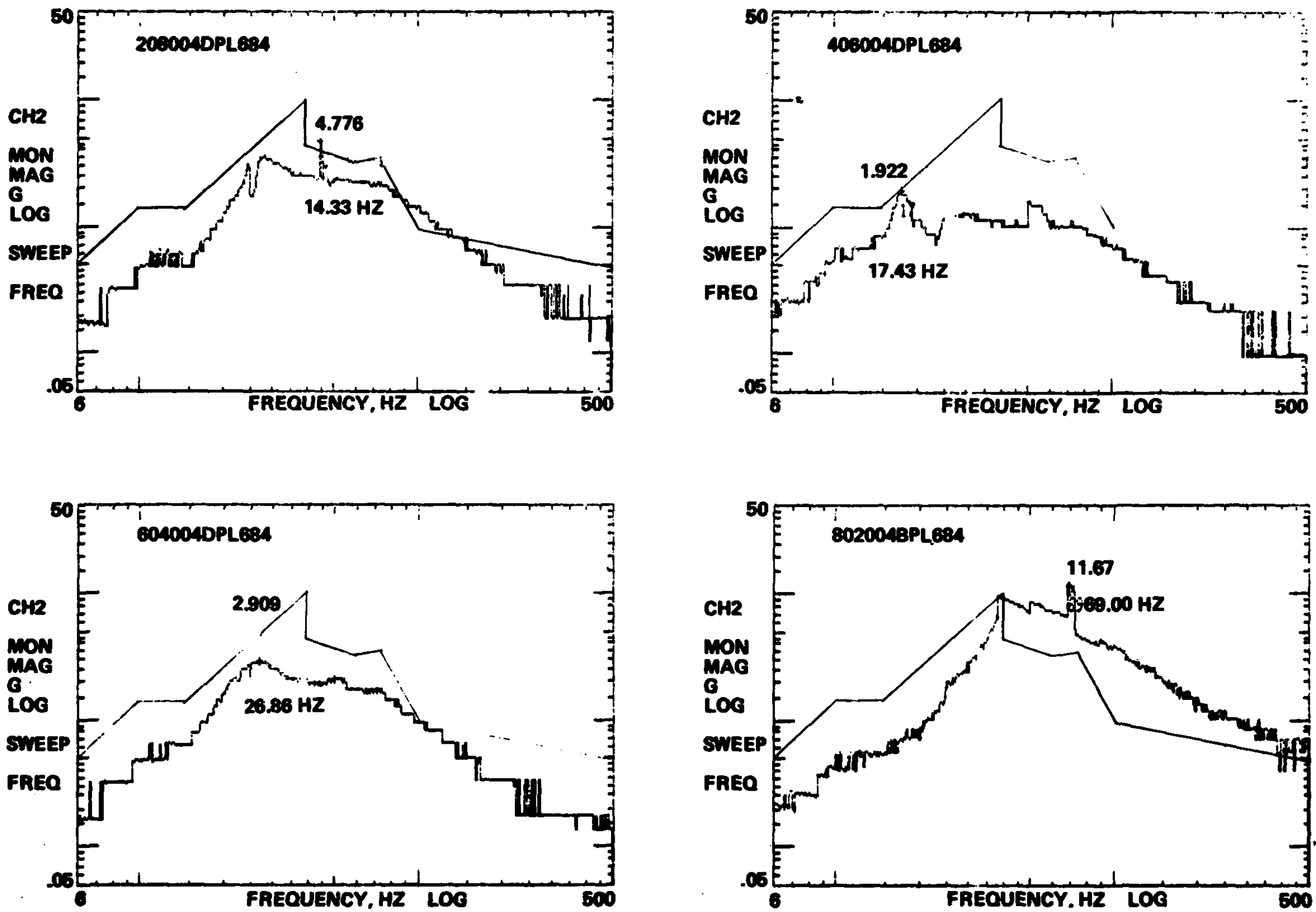

FIGURE 8 VIBRATION OUTPUT FOR NSWC FOAMS 208004DPL684 TO 802004BPL684.

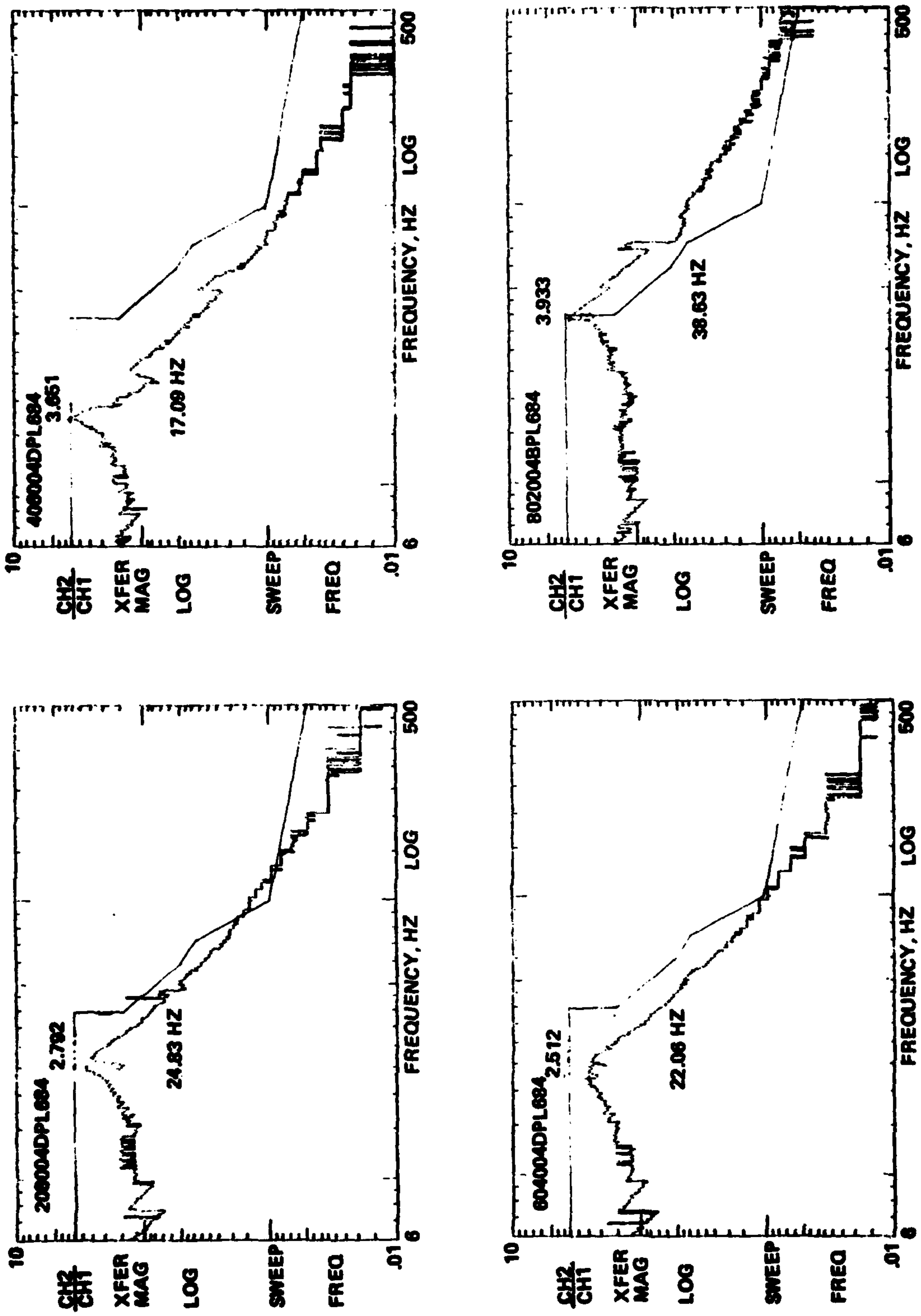

FIGURE 9 VIBRATION TRANSMISSIBILITY FOR NSWC FOAMS 208004DPL684 TO 802004BPL684.

TABLE 1 MECHANICAL PROPERTIES OF NSWC POLYOL MODIFIED FOAMS

FOAM FORMULATION	TENSILE STRENGTH (psi)	ELONGATION (%)	YOUNG'S MODULUS (psi)	DENSITY (lbs./cu.ft.)
208004BT650	21.8	509	6.30	3.74
406004BT650	22.0	373	6.74	3.85
604004BT650	15.6	222	7.20	3.73
802004BT650	11.5	139	9.40	4.17
208004DPL381	37.6	660	8.18	3.35
406004BPL381	40.3	595	10.82	4.04
604004BPL381	30.9	386	13.37	3.89
802004BPL381	16.0	200	11.84	3.98
208004DPL684	41.3	559	11.46	3.31
406004DPL684	39.2	327	10.02	3.60
604004DPL684	26.8	227	11.39	3.71
802004BPL684	33.8	161	24.34	3.62

Substitution of Teracol 650, a lower molecular weight poly(oxytetramethylene)glycol, for Polymeg 2000 did not yield any improvement in the mechanical properties. The tensile strength (Figure 10) for 20/80 - PL 718/T 650 foam was substantially lower than that for PL 718/PM 2000 while the two foam systems had similar tensile properties at higher PL 718/T 650 ratios.

Both the PL 381/PM 2000 and PL 684/PM 2000 foam systems do offer improved tensile strength properties when compared to the standard PL 718/PM 2000 system (Figure 10). Of the eight formulations studied, six of these had foam tensile properties which met or exceeded the requirements of MIL-F-81334B.

With regard to the elongation properties of these foams, only the PL 381/PM 2000 system had higher elongations than the standard PL 718/PM 2000 system (Figure 11). As the PM 2000 content of these foams decreases the elongation values also show a sharp decline. In the case of the PL 381/PM 2000 foams, the results show that foams with as little as 50% PM are still capable of meeting the military specification for elongation (450% at 4 lb/cu.ft. density). The other systems fall below this 450% elongation point when the PM contents are less than 70%.

The modulus values of these foams showed some variability though in general an increase in modulus was found with decreasing PM content (Figure 12). This is in contrast to the gradual decrease in the modulus of the standard PL 718/PM 2000 system with decreasing amounts of PM in the polyol mixture. The correlation between damping properties and modulus previously reported (Reference 3) did not hold for these foams.

CONCLUSIONS

1. Modified foam formulations in a 4 lb/cu.ft. density have been made which pass the MIL-F-81334B(AS) specification for vibration damping. The following formulations provided the best damping results: 208004BT650, 406004BT650, 604004BT650, 802004BT650, 208004DPL684, 406004DPL684, 604004DPL684, and 208004DPL381.

2. From this group of best damping foams only 406004DPL684 and 208004DPL381 met the tensile strength requirements of MIL-F-81334B(AS).

3. The elongation requirement (450%) was met by 208004BT650 and 208004DPL381.

RECOMMENDATIONS

The best of the modified foam systems judged on the basis of their damping response should be bonded to the electronics support mounts and subjected to vibration testing.

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[3]See footnote 3 on page 5.

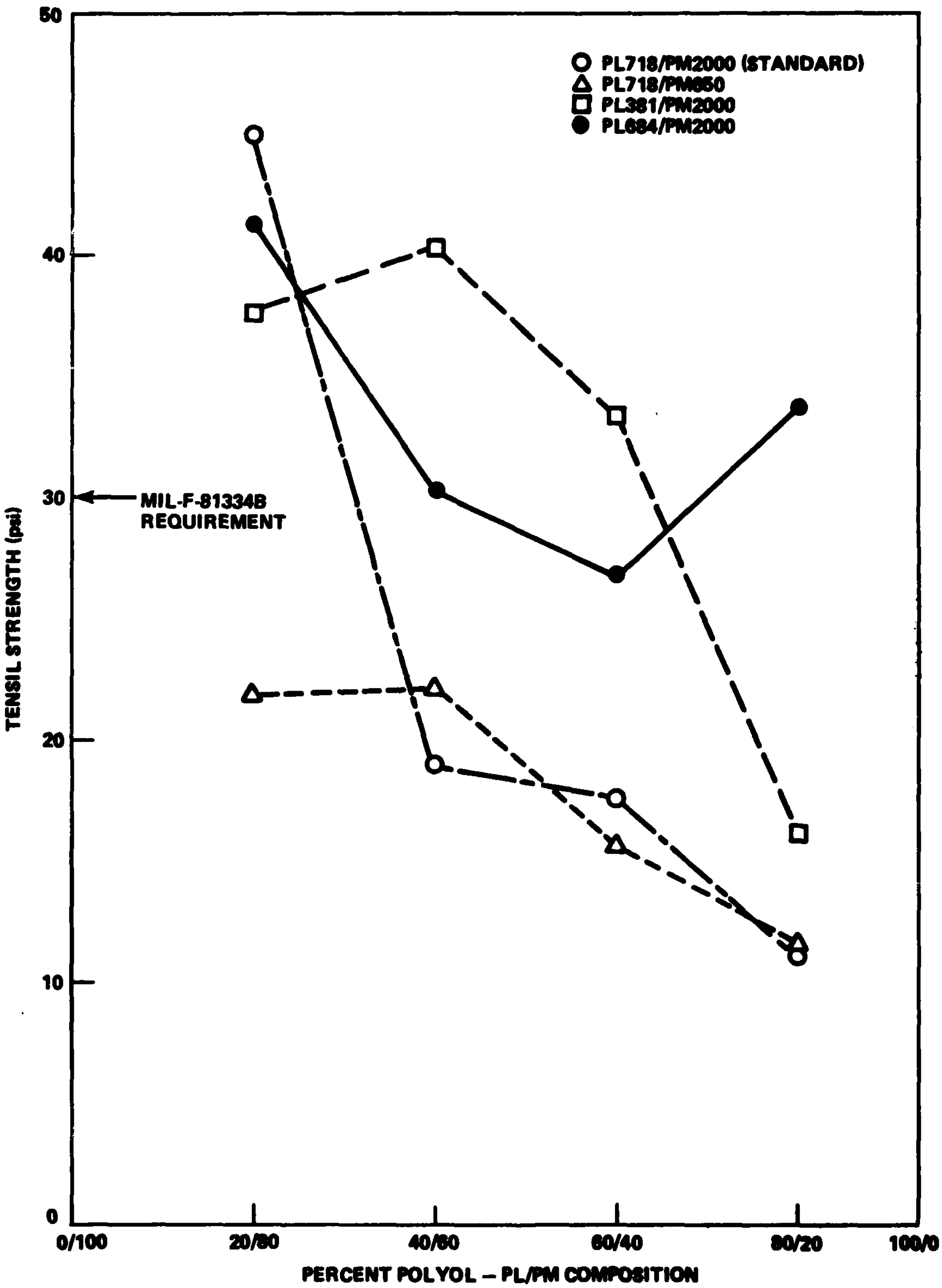

FIGURE 10 TENSILE PROPERTIES OF POLYOL MODIFIED PL718/PM2000 FOAMS

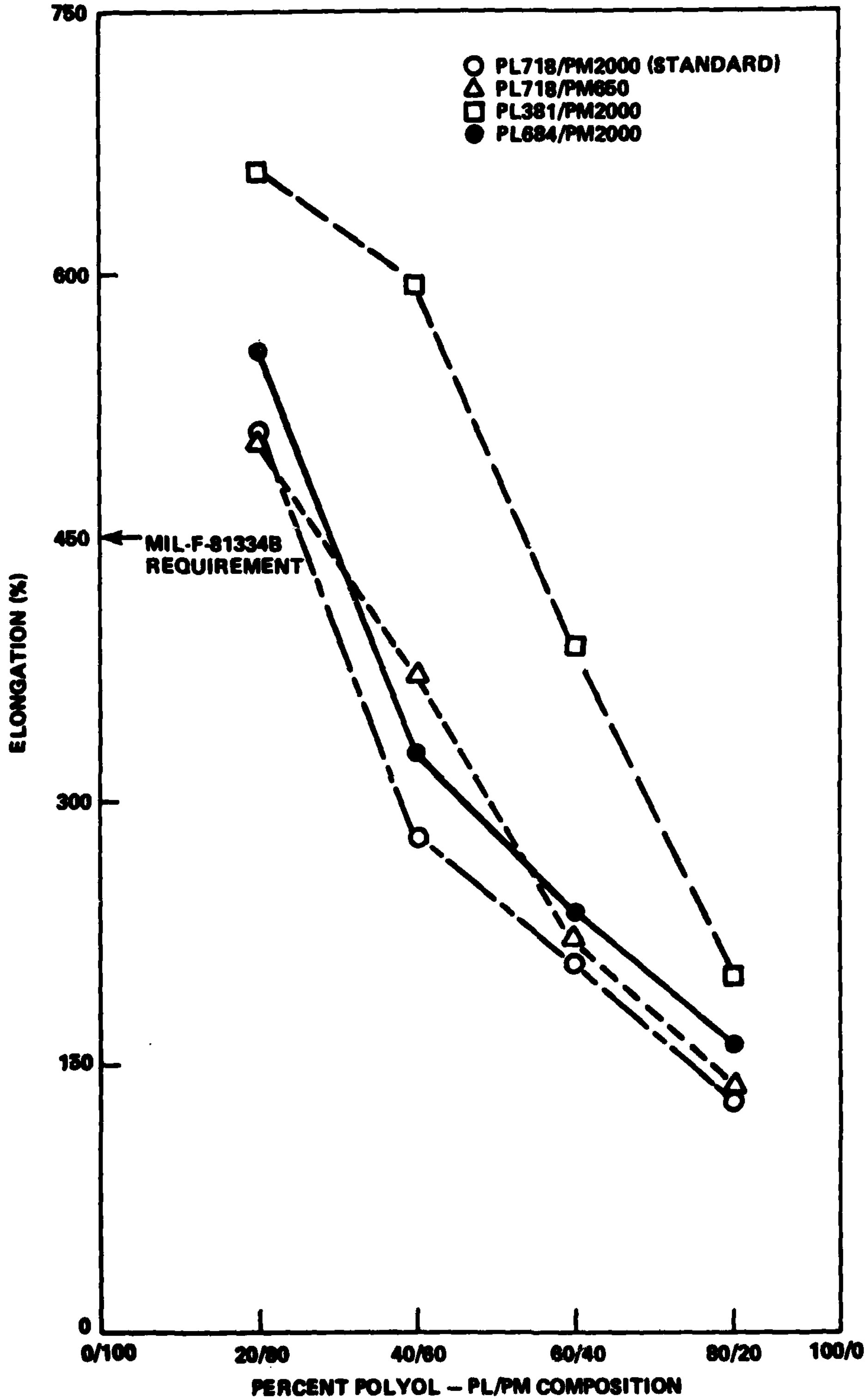

FIGURE 11 ELONGATION PROPERTIES OF POLYOL MODIFIED PL718/PM2000 FOAMS

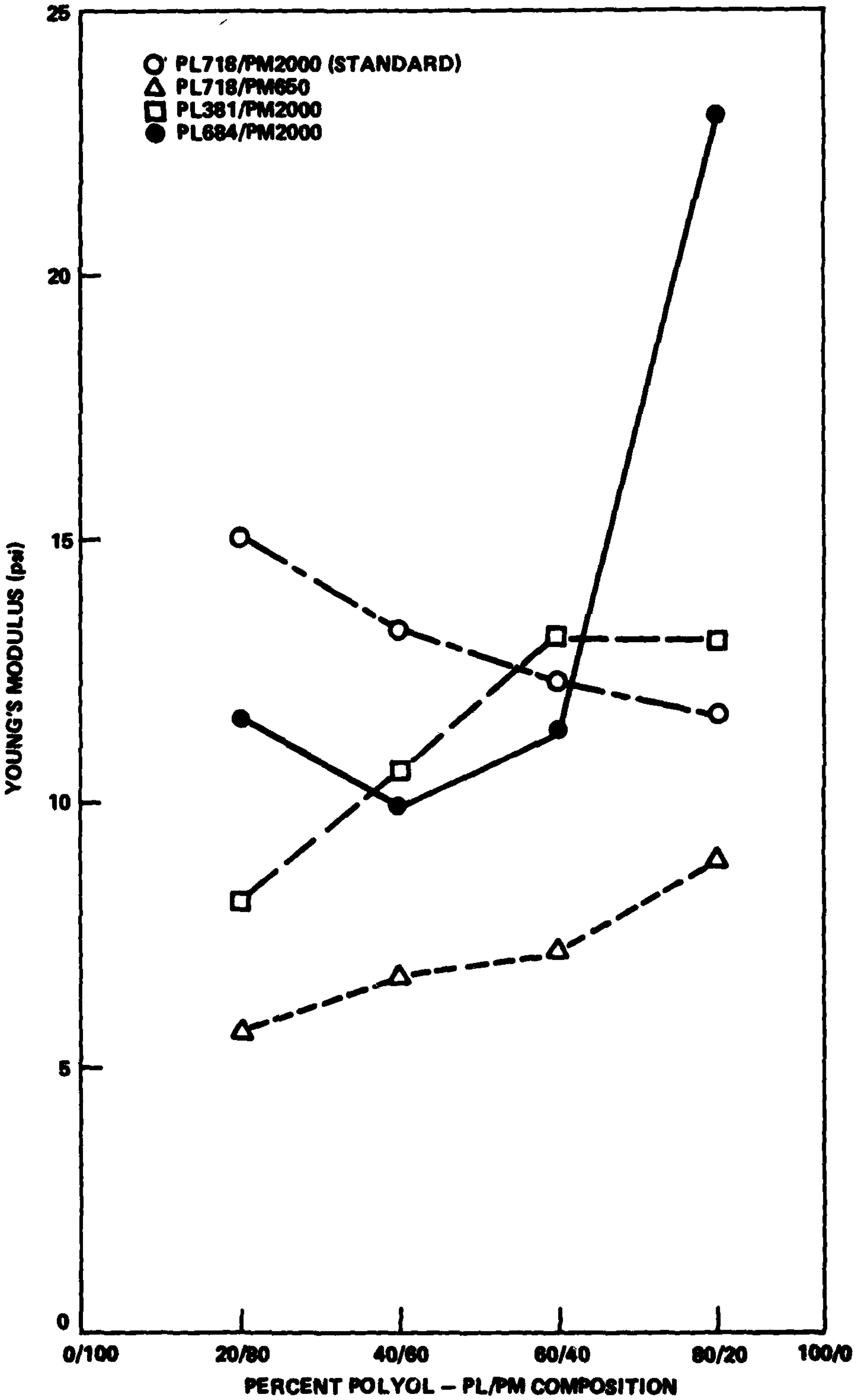

FIGURE 12 YOUNG'S MODULUS OF POLYOL MODIFIED PL718/PM2000 FOAMS

CHEMICAL GLOSSARY

RESINS

PL-718	Pluracol 718 - poly(oxypropylene)triol (BASF Wyandotte Chemical Co.)
PL-381	Pluracol 381 - poly(oxypropylene)triol (BASF Wyandotte Chemical Co.)
PL-684	Pluracol 684 - graft polyol (BASF Wyandotte Chemical Co.)
T-650	Teracol 650 - poly(oxytetramethylene)glycol MW650 (Dupont Co.)
PM-2000	Polymeg 2000 - poly(oxytetramethylene)glycol MW 2000 (Quaker Oats Co.)

SURFACTANTS

DC 196	silicone surfactant (Dow Corning Co.)
B 3136	silicone surfactant (Th. Goldschmidt Products Co.)

AMINE CATALYSTS

33LV	Dabco 33LV is a 33% solution of triethylenediamine in dipropylene glycol (Air Products).
NEM	N-ethylmorpholine (Jefferson Chemical)

TIN CATALYST

T9	Stannous octoate (M & T Chemicals)

ISOCYANATE

TD 80	Mondur TD*80 80/20 mixture of toluenediisocyanate (Mobay Chemical Co.)

COLORANT

DS 1822	Black inorganic pigment in an inert liquid (Conap Inc.)

APPENDIX A

FOAM FORMULATIONS

802004BT650

960	PL 718
240	T 650
17.7	H_2O
2.40	33LV
3.60	NEM
7.6	B 3136
6.0	DS 1822
1.44	T 9
340	TD 80

Mix 30 seconds
1500 RPM
Cream 40 seconds

604004BT650

720	PL 718
480	T 650
17.9	H_2O
2.40	33LV
2.40	NEM
6.0	B 3136
6.0	DS 1822
2.4	T 9
386	TD 80

Mix 20 seconds
1500 RPM
Cream 30 seconds

406004BT650

480	PL 718
720	T 650
15.7	H_2O
2.40	33LV
2.40	NEM
6.0	B 3136
6.0	DS 1822
3.00	T 9
411	TD 80

Mix 20 seconds
1500 RPM
Cream 30 seconds

208004BT650

240	PL 718
960	T 650
15.7	H_2O
2.40	33LV
6.3	B 3136
6.0	DS 1822
5.20	T 9
447	TD 80

Mix 15 seconds
1500 RPM
Cream 20 seconds

802004BPL381

960	PL 381
240	PM 2000
19.7	H_2O
3.60	33LV
2.40	NEM
12.0	B 3136
6.0	DS 1822
2.50	T 9
300	TD 80

Mix 25 seconds
1500 RPM
Cream 35 seconds

604004BPL381

720	PL 381
480	PM 2000
21.9	H_2O
2.70	33LV
15.0	B 3136
6.0	DS 1822
4.00	T 9
326	TD 80

Mix 20 seconds
1500 RPM
Cream 30 seconds

406004BPL381

480	PL 381
720	PM 2000
17.7	H_2O
2.40	33LV
3.80	NEM
6.0	B 3136
6.0	DS 1822
3.00	T 9
286	TD 80

Mix 15 seconds
1500 RPM
Cream 25 seconds

208004BPL381

240	PL 381
960	PM 2000
20.7	H_2O
2.70	33LV
12.0	DC 196
6.0	DS 1822
8.00	T 9
320	TD 80

Mix 15 seconds
1500 RPM
Cream 20 seconds

802004BPL684

960	PL 684
240	PM 2000
19.7	H_2O
3.60	33LV
12.0	B 3136
6.0	DS 1822
2.12	T 9
282	TD 80

Mix 15 seconds
1600 RPM
Cream 25 seconds

604004BPL684

720	PL 684
480	PM 2000
18.4	H_2O
2.70	33LV
14.2	DC 196
6.0	DS 1822
4.20	T 9
276	TD 80

Mix 15 seconds
1600 RPM
Cream 25 seconds

406004BPL684

480	PL 684
720	PM 2000
18.4	H_2O
2.70	33LV
15.0	DC 196
6.0	DS 1822
5.60	T 9
285	TD 80

Mix 15 seconds
1600 RPM
Cream 20 seconds

208004BPL684

240	PL 684
960	PM 2000
20.4	H_2O
2.70	33LV
21.0	DC 196
6.0	DS 1822
9.00	T 9
313	TD 80

Mix 15 seconds
1600 RPM
Cream 20 seconds

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